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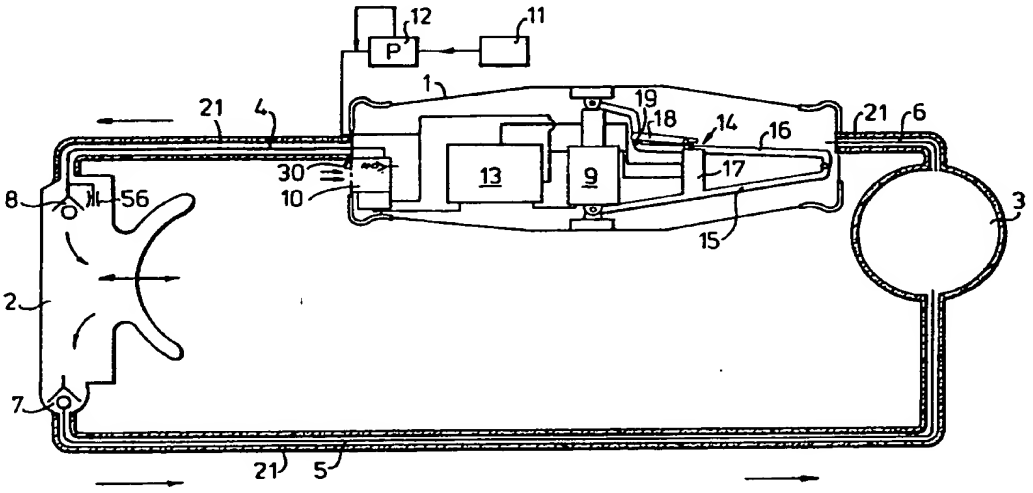
(54) Title: A BREATHING SYSTEM FOR SMOKE DIVING AND THE LIKE



(57) Abstract

A closed or semi-closed breathing system for smoke diving and the like includes a pneumatically controlled breathing bag (1) communicating in a circulation (4, 5, 6) with a breathing mouthpiece or breathing mask (2) for a user and with an absorption means (3) for exhaled CO_2, a pneumatic actuator (9) arranged for alternating expansion and contraction of the breathing bag (1) in accordance with the breathing pattern of the user, and a pressurized gas source (11) coupled to the breathing bag (1) to supplement the breathing gas therein. The system includes a mode regulator (10) arranged to control the actuator's actuation of the breathing bag (1) while simultaneously maintaining an overpressure in the breathing mask (2) in relation to the surroundings, and a dosing means (13) for the supply of a metered gas quantity to the breathing bag (1) in dependence on its degree of filling.

A breathing system for smoke diving and the like

The present invention relates to a closed or semi-closed breathing system for smoke diving and the like, comprising a pneumatically controlled breathing bag communicating in a circulation with a breathing mouthpiece or breathing mask for a user and with an absorption means for exhaled CO_2, a pneumatic actuator arranged for alternating expansion and contraction of the breathing bag in accordance with the breathing pattern of the user, and a pressurized gas source coupled to the breathing bag to supplement the breathing gas therein.

There are known a number of embodiments of self-contained breathing systems. Breathing equipment for smoke diving preferably is based on the supply of breathing gas through a breathing valve, whereas exhaled gas is "dumped" directly to the surroundings through a one-way valve ("open breathing system"). Alternative types of breathing equipment are based on recovery of exhaled gas in a "closed" or "semi-closed" circulation. This implies that exhaled gas - partly or completely - is purified of CO_2 and supplied with oxygen so that it is again suitable as a breathing gas. With closed or semi-closed breathing systems there is achieved a long service life with a moderate gas supply, but they are normally heavy to breathe with because of the fact that the gas is recirculated by lung force. In comparison, good open breathing systems are easy to breathe with, but have a considerably shorter service life since one is dependent on keeping the weight low. A substantial advantage with open breathing systems is that one is able to maintain a safety pressure (weak overpressure) in the breathing mask, so that the ingress of gases which are harmful to the health, is prevented.

The object of the invention is to provide a closed or semi-closed breathing system which has a safety overpressure in the breathing mask and which utilizes the available breathing gas reservoir optimally, and wherein the system is reliable in service, is simple and reasonable to produce, and has a small weight and a long service life.

According to the invention there is provided a breath-

ing system of the type stated in the introduction which is characterized in that it includes a mode regulator arranged to control the actuator's actuation of the breathing bag while simultaneously maintaining an overpressure in the breathing mask in relation to the surroundings, and a dosing means for the supply of a metered gas quantity to the breathing bag in dependence on its degree of filling.

In the present beathing system a small breathing work is achieved in that the pressure energy of the supplied oxygen is used to assist the recirculation of the breathing gas, the oxygen supply taking place through the pneumatic actuator which alternatingly expands and contracts the breathing bag in accordance with the breathing pattern of the user. This is a technique which is already used in a semi-closed breathing system for underwater diving, and in this connection reference is made to US patent No. 4 793 340. The technique has, however, not been previously used in a closed breathing system. In the present breathing system it is an important point that this technique is utilized to establish a "safety pressure" in the breathing mouthpiece or breathing mask of the user, something which prevents the ingress of gases which are harmful to the health. This is of great importance as viewed from the safety point of view, and is - as far as one knows - not achieved in any other self-contained closed breathing system.

In the breathing system according to the invention, the mode regulator sees to it that the actuator is supplied with compressed oxygen, or alternatively that supplied oxygen is "vented" to the breathing bag which thereby controls the recirculation of breathing gas, at the same time as it is ensured that a small safety overpressure is maintained in the breathing mask during inhalation as well as during exhalation. The actuator is so dimensioned that the oxygen quantity received thereby and thereafter "vented" to the breathing bag, is somewhat smaller than the quantity absorbed in the respiration. It is therefore necessary to inject a certain oxygen quantity directly into the circulation of the system, to maintain the oxygen level in the breathing gas. According to the invention, this is achieved in that the dosing means is arranged to discharge a metered quantity of gas into the breathing bag each time when,

during exhalation, there is not achieved a sufficient filling of the breathing bag. Thus, the system is not, like many other closed oxygen apparatuses, based on a fixed injection of gas rich in oxygen, but utilizes the available gas reservoir optimally. It has been found to be advantageous to dimension the system so that the maximum driving pressure of the actuator is approximately ±15 cm water column. In practice this implies that the actuator is able to compensate for the work which the lungs of the user otherwise would have to carry out in order to overcome restrictions through one-way valves, hoses, CO_2 absorber, etc. in the system.

An advantageous embodiment of the system according to the invention is characterized in that the circulation of the system includes conduit stretches of which the outer surface is covered by a relatively thick porous material which, saturated with water, utilizes the evaporation of the water for cooling down the breathing gas circulating in the circulation during operation.

The breathing system then is constructed in such a manner that surrounding gas flows past the surface and causes an efficient evaporation. The evaporation heat is partly taken from the wet surface which is cooled down considerably. Further, the wet surface of the conduit stretches and possible other cooled-down surfaces in the system have a good thermal conduction to internal surfaces of the breathing system, so that an efficient cooling of the breathing gas is achieved. Such an arrangement for cooling of the breathing gas opens up for considerable advantages as compared to traditional breathing systems wherein the temperature of inhaled gas may be well above the body temperature. In addition, this solution has the advantage that the evaporation increases with the surrounding temperature, so that the system manages to maintain an acceptable breathing gas temperature even in rather warm surroundings. Another advantage of this solution is that wetting with water also has fire-technical advantages. The system will be able to be ready for operation in that it is, e.g., immersed in a container of water. A thick porous material will be able to absorb a considerable quantity of water, and the cooling therefore can take place over a relatively long time without another wetting of the porous

material.

The invention will be further described below in connection with an exemplary embodiment with reference to the drawings, wherein

Fig. 1 shows a schematic view, partly in section, of a preferred embodiment of a breathing system according to the invention;

Fig. 2 shows a sectional view of the mode regulator in Fig. 1 on an enlarged scale, and

Fig. 3 shows an enlarged sectional view of the breathing bag in Fig. 1, the Figure showing more detailed sectional views of the elements and units arranged within the breathing bag.

The embodiment shown in Fig. 1 constitutes a closed breathing system wherein a breathing bag 1, a breathing mask 2 and a CO_2 absorbing means 3 are connected in series in a closed circuit or circulation, said units being interconnected through conduit stretches 4, 5 and 6. The breathing gas is inhaled from the breathing bag 1 through the breathing mask 2 which is provided with one-way valves 7 and 8 ensuring that inhaled and exhaled gases are not mixed. Exhaled gas passes via the means 3, which consists of a container containing a CO_2 absorbing material, into the breathing bag 1.

Within the breathing bag 1 there is arranged a pneumatic actuator 9 consisting of a cylinder/piston unit (see Fig. 3) which, as shown, is articulated to the side walls of the breathing bag in the central region thereof. The actuator causes alternating expansion and contraction of the breathing bag in accordance with the breathing pattern of the user, as further described below. For the control of the actuator 9, there is provided a mode regulator 10 seeing that the actuator is supplied with compressed oxygen, or alternatively that supplied oxygen is vented to the breathing bag, as also further described below. Pressurized oxygen is supplied from a source 11 through a pressure reducing valve 12.

In the illustrated embodiment, the actuator 9 is dimensioned such that the oxygen quantity which is received and thereafter vented to the breathing bag, is somewhat smaller than the quantity absorbed in the user's respiration. In order to

maintain the oxygen level in the breathing gas, it is therefore necessary to inject a certain oxygen quantity directly into the circulation. For this purpose there is provided a dosing means 13 which is arranged to discharge a metered oxygen quantity into the breathing bag 1 each time when, during exhalation, there is not achieved a sufficient filling of the breathing bag.

In order to record the filling degree of the breathing bag in each exhalation (expansion of the breathing bag), there is provided a sensing means 14 in combination with a pair of arms 15, 16 following the movement of the breathing bag, the arms at one of their ends being pivotally connected to each other, and at their other ends being articulated to the side walls of the breathing bag at the same places where the actuator 9 is coupled to the breathing bag. The sensing means comprises a holding member 17 fixed to one arm 15 and extending in the direction of and past the other arm 16, a lever 18 pivotally connected to the free end of the holding member, a transverse pin 19 fixed to the arm 16 and cooperating with the lever 18, and a valve 20 (see Fig. 3) provided in the holding member and arranged to be actuated by the lever 18. This valve is opened when the lever 18 is lifted by the transverse pin 19 when the breathing bag 1 is filled beyond a certain filling degree, and then delivers a "blocking signal" to the dosing means 13, as further described below.

As appears from Fig. 1, the outer surfaces of the conduit stretches 4, 5, 6 are covered by a relatively thick layer of a material 21 which is porous and water-absorbing, and which - in operation - is intended to be saturated with water, the water then evaporating and providing for cooling-down of the breathing gas circulating in the circulation, as discussed above. Also the container 3 is covered by the water-absorbing material, and in particular those parts of the circulation located downstream of the container 3, may be extended in a suitable manner, with a view to achieving a large, efficient evaporation surface to the surrounding atmosphere.

The construction of the mode regulator 10 is shown more in detail in Fig. 2. It consists of a housing 22 containing a sensing diaphragm 23 dividing the housing into a pair of chambers 24, 25. The chamber 24 communicates with the outer atmosphere

through a pair of apertures 26, 27, whereas the chamber 25 communicates with the breathing mask 2 through the conduit 4 and is supplied with breathing gas from the breathing bag 1 through a one-way valve 28. In the chamber 24 there is provided a spring 29 for acting upon the sensing diaphragm 23, so that in operation it is affected by a certain spring force in addition to the atmosphere pressure in the chamber 24. In this manner there is achieved a certain overpressure or safety pressure in the system, when the spring is activated. The spring 29 is arranged in a cap 30 which is screwed into the housing 22 and can be screwed in to a greater or smaller extent, for setting of a desired spring prestressing force and thereby a desired overpressure. It is obvious that the diaphragm-influencing means may be carried out in many other ways than the illustrated spring and cap, but it is essential that the means is easily accessible to the user.

The sensing diaphragm 23 is mechanically coupled to a lever 31 for alternative actuation of a first and a second valve 32 and 33, respectively, of which a first valve 32 communicates with the actuator 9 through a conduit 34, and the second valve 33 is coupled to a conduit 35 communicating with the pressurized gas source 11 (through the reducing valve 12) as well as with the actuator 9, as shown in Fig. 3.

The construction of the actuator 9 and the dosing means 13 is shown more in detail in Fig. 3.

As shown, the actuator 9 consists of a cylinder 36 and a piston 37 having, as viewed in Fig. 3, an upper pressure surface 37a which is substantially smaller than the lower pressure surface 37b of the piston. The upper cylinder compartment 36a is connected to the pressurized gas source 11 through a conduit 38, and the lower cylinder compartment 36b is connected to the valves 32, 33 of the mode regulator through a conduit 39 (passing through the dosing means 13) and the conduit 34. Thus, the smallest pressure surface 37a of the piston stands under a constant pressure influence from the pressurized gas source 11, so that the actuator 9 changes pressure direction according as its lower cylinder compartment 36b is supplied with gas from the pressurized gas source (through the mode regulator valve 33) or is vented (through the valve 32). As an alternative to connecting the pressurized gas source to the upper cylinder compart-

ment, the upper side of the piston instead might be acted upon by a continuously acting spring force.

The dosing means 13 includes a small gas reservoir 40 which is arranged to be filled with oxygen through a first valve or inlet valve 41 which is connected to the pressurized gas source 11 through a conduit 42 and the conduit 38, and further is arranged to be discharged into the breathing bag through a second valve or outlet valve 43. The valves 41 and 43 are arranged to be opened and closed alternately by an operating means in the form of a spring-loaded lever 44 which, in its initial position, keeps the valve 41 open. In the conduit 39 between the valves 32, 33 of the mode regulator 10 and the lower cylinder compartment of the actuator 9, there is connected a unit consisting of a pair of spring-loaded and oppositely directed one-way valves 45, 46 connected in parallel, and a chamber 47 connected in parallel to the valves and which is divided in two parts by a control diaphragm 48, as shown in Fig. 3. When gas is flowing through one or the other of the one-way valves 45, 46, according to the direction of flow in the conduit 39, the pressure drop across the one-way valve concerned causes the diaphragm 48 to be pressed in the flow direction of the gas. This is utilized to control the dosing means 13, so that it discharges the gas quantity in the reservoir 40 into the breathing bag 1 (through the valve 43) each time when, during exhalation, there is not achieved a sufficient filling of the breathing bag. For this purpose the control diaphragm 48 is coupled to an operating rod 49 which is moved to the right and affects the lever 44 when the diaphragm 48 is pressed to the right and opens the valve 43, provided that the movement of the operating rod 49 is not prevented as a result of a "blocking signal" delivered from the sensing means 14. As mentioned above, this blocking signal is provided from the valve 20. This is connected to the pressurized gas source 11 through a conduit 50, the upper cylinder compartment 36a of the actuator cylinder 36 and the conduit 38, and is further connected through a conduit 51 to a cylinder/piston unit 52 arranged in the dosing means 13 and having a spring-loaded blocking piston 53 and an associated venting valve 54. The blocking signal consists in that the blocking piston 53 is pressure-actuated by opening of the valve

20, so that the piston is moved to the left and actuates a blocking lever 55 preventing said movement of the operating rod 49 even if the control diaphragm 48 is pressed to the right. The blocking signal is nullified in that the control diaphragm 48 is pressed to the left, so that the blocking lever 55 is pivoted by actuation from the operating rod 49 and opens the venting valve 54, so that the blocking piston 53 by spring influence is returned to its initial position.

The operation of the breathing system will be further described below.

As soon as the user of the system starts inhalation, the pressure in the chamber 25 of the mode regulator 10 falls so that the sensing diaphragm 23 is pressed towards the chamber and opens the valve 32. Hereby venting of gas from the lower cylinder compartment 36b of the actuator 9 starts, so that the actuator contracts the side faces of the breathing bag 1, so as to maintain a certain safety overpressure in the breathing mask 2. With exhalation the pressure in the breathing mask rises, and this pressure increase is transferred through a passage 56 to the chamber 25 of the mode regulator, so that the sensing diaphragm 23 is pressed outwards towards the chamber 24. Thereby the valve 33 is opened, so that the lower cylinder compartment of the actuator 9 is supplied with compressed gas (oxygen) from the pressurized gas source.

The main supply of oxygen to the breathing bag takes place through the venting valve 32 of the mode regulator. Since the actuator as mentioned is dimensioned so as to supply a bit to little oxygen, the dosing means 13 also injects the metered oxygen quantity from the reservoir 40 to the breathing bag 1 after each exhalation wherein the breathing bag has not been sufficiently filled with breathing gas. The injection of oxygen takes place at the same time as oxygen is vented from the actuator and the control diaphragm 48 is pressed to the right and opens the valve 43 by way of the operating rod 49 and the lever 44, that is, just after the inhalation phase has started. The condition for opening of the valve 43 is that the sensing means 14 has not delivered a "blocking signal", which signal is delivered from the valve 20 when the lever 18 is lifted by the transverse pin 19 on the arm 16. As mentioned above, the

blocking signal causes that the control diaphragm 48 is not able to move the lever 44 to the right and open the valve 43. The blocking signal is nullified automatically when the breathing bag again gets into the exhalation mode and the diaphragm 48 is pressed to the left and opens the venting valve 54.

In the embodiment described above it has been emphasized that the equipment is to be completely "closed", since this gives advantages with respect to safety in inflammable surroundings. In principle, there is nothing to prevent that the equipment is made "semi-closed", for example with a view to sports diving. In that case it is natural to take as ones basis that the oxygen supply through the pneumatic actuator is larger than the consumption, and that an automatic means is constructed which dumps gas each time the breathing bag in exhalation is filled beyond a given level. Further, it is conceivable that the pneumatic assistance is based on gas supply from one gas reservoir, and that the compensation of oxygen takes place from another one, without this having to change the structure to a substantial degree.

In cases where the system according to the invention is to be used in a gas-filled atmosphere, it is natural, because of weight, size, etc., to build the mode regulator into the breathing bag, as shown and described. In connnection with e.g. diving, hydrostatic conditions will make it natural to build the mode regulator into the breathing mouthpiece or breathing mask. The breathing system will be operative as soon as the reducing valve supplies gas to the pneumatics of the system.

As regards the arrangement for cooling-down of the breathing gas, it will be clear that this may be applied for virtually all types of breathing systems used in gas-filled surroundings.

Patent Claims

1. A closed or semi-closed breathing system for smoke diving and the like, comprising a pneumatically controlled breathing bag (1) communicating in a circulation (4, 5, 6) with a breathing mouthpiece or breathing mask (2) for a user and with an absorption means (3) for exhaled CO_2, a pneumatic actuator (9) arranged for alternating expansion and contraction of the breathing bag (1) in accordance with the breathing pattern of the user, and a pressurized gas source (11) coupled to the breathing bag (1) to supplement the breathing gas therein, CHARACTERIZED IN that it includes a mode regulator (10) arranged to control the actuator's actuation of the breathing bag (1) while simultaneously maintaining an overpressure in the breathing mask (2) in relation to the surroundings, and a dosing means (13) for the supply of a metered gas quantity to the breathing bag (1) in dependence on its degree of filling.

2. A breathing system according to claim 1, CHARACTERIZED IN that the circulation comprises conduit stretches (4, 5, 6) of which the outer surface is covered by a relatively thick porous material (21) which, saturated with water vapour, utilizes the evaporation of the water for cooling down the breathing gas circulating in the circulation during operation.

3. A breathing system according to claim 1 or 2, CHARACTERIZED IN that the mode regulator (10) comprises a valve means (32, 33) and a sensing diaphragm (23) cooperating therewith, of which one side is influenced by the surrounding atmosphere pressure and by a spring means (29, 30) for maintaining said overpressure in the system, and of which the other side is influenced by the gas pressure in the breathing mask (2), the movement of the sensing diaphragm (23) from a central position being transferred to the valve means (32, 33) which, in dependence on the movement direction of the diaphragm (23), either opens for the supply of pressurized gas to the actuator (9), or vents the actuator.

4. A breathing system according to claim 3, CHARACTERIZED IN that the actuator (9) comprises a cylinder/piston unit (36, 37) coupled to the pressurized gas source (11) through the mode regulator (10), the valve means (32, 33) thereof comprising a

first valve (32) which is opened for venting of the actuator (9), and a second valve (33) which is opened for the supply of pressurized gas to the actuator (9).

5. A breathing system according to claim 4, CHARACTERIZED IN that the piston (37) of the valve actuator (9) has opposite pressure surface (37a, 37b) with substantially different areas, the smallest pressure surface (37a) being under constant pressure influence from the pressurized gas source (11), so that the actuator (9) changes pressure direction according as its opposite side is supplied with gas from the pressurized gas source (11) or is vented.

6. A breathing system according to any of the claims 3-5, CHARACTERIZED IN that the spring force of the spring means (29, 30) is adjustable, for adjustment of the overpressure in the system.

7. A breathing system according to claim 3 and 4, CHARACTERIZED IN that the dosing means (13) comprises a gas reservoir (40) which is connected to the pressurized gas source (11) through a first valve (41) and to the interior of the breathing bag (1) through a second valve (43), said valves being arranged to be actuated by a common operating member (44), and that a control diaphragm (48) is arranged in a conduit connection (39) between the valve means (32, 33) of the mode regulator (10) and the actuator (9), which diaphragm is coupled to the operating member (44) and provides for opening of the second valve (43) during venting of the actuator (9).

8. A breathing system according to claim 7, CHARACTERIZED IN that it includes a sensing means (14) sensing whether there is sufficient gas in the breathing system, and which, in case of overstepping of a chosen filling degree of the breathing bag (1), is arranged to actuate a blocking means (52, 53) then preventing the operating member (44) of the dosing means (13) from opening said second valve (43).

9. A breathing system according to claim 8, CHARACTERIZED IN that the blocking means consists of a pneumatic piston (53) coupled to the pressurized gas source (11) through a valve means (20) in the sensing means (14).

Fig.1.

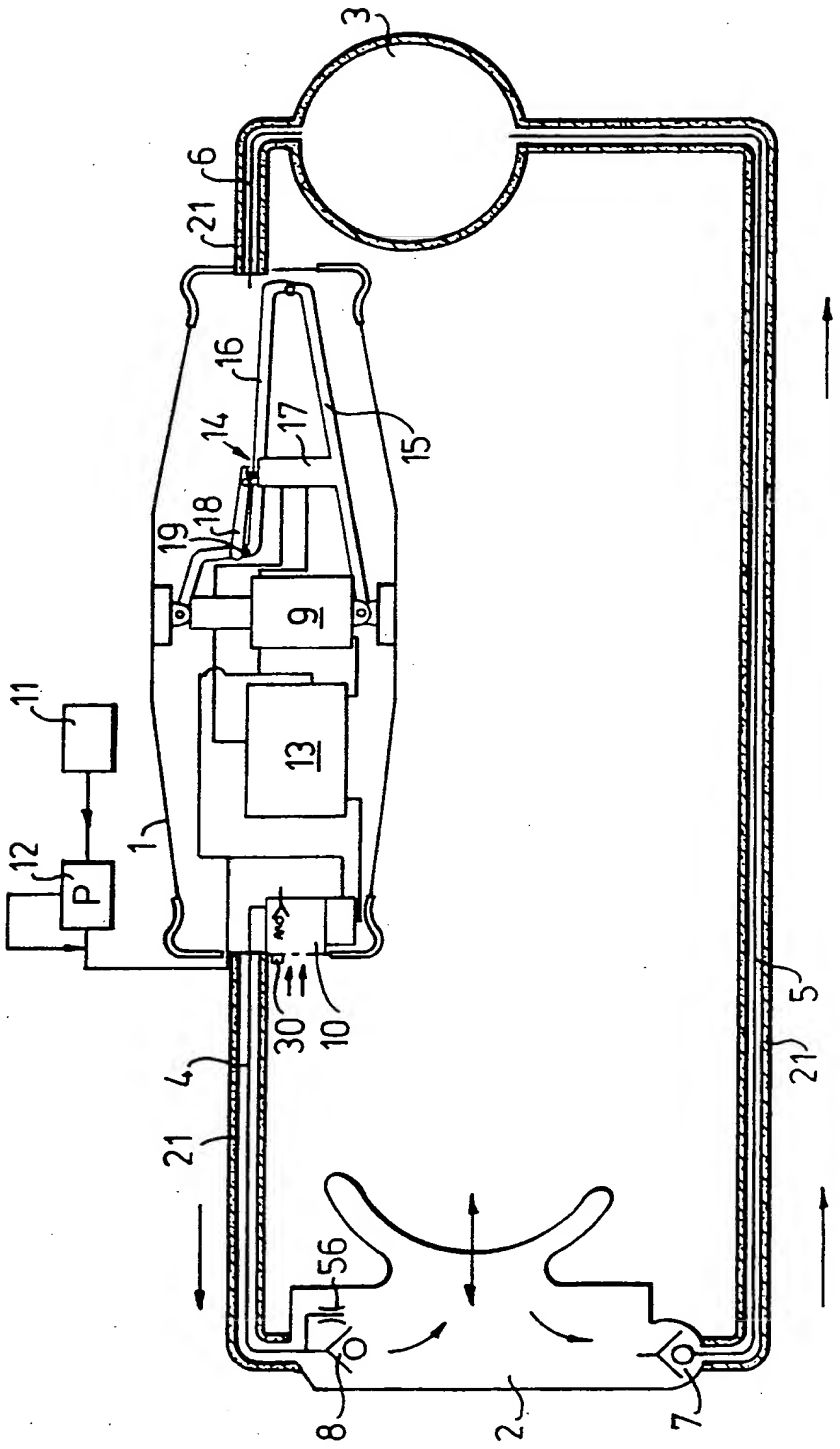


Fig.2.

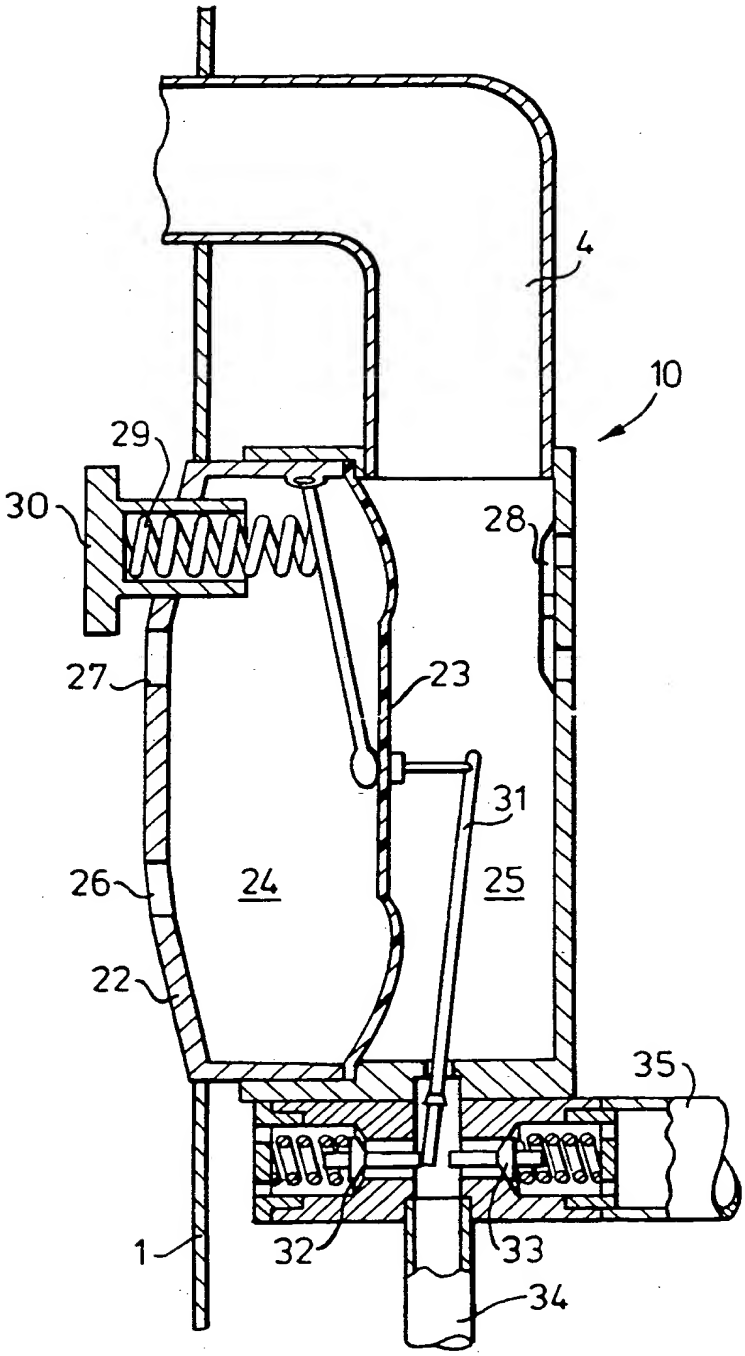
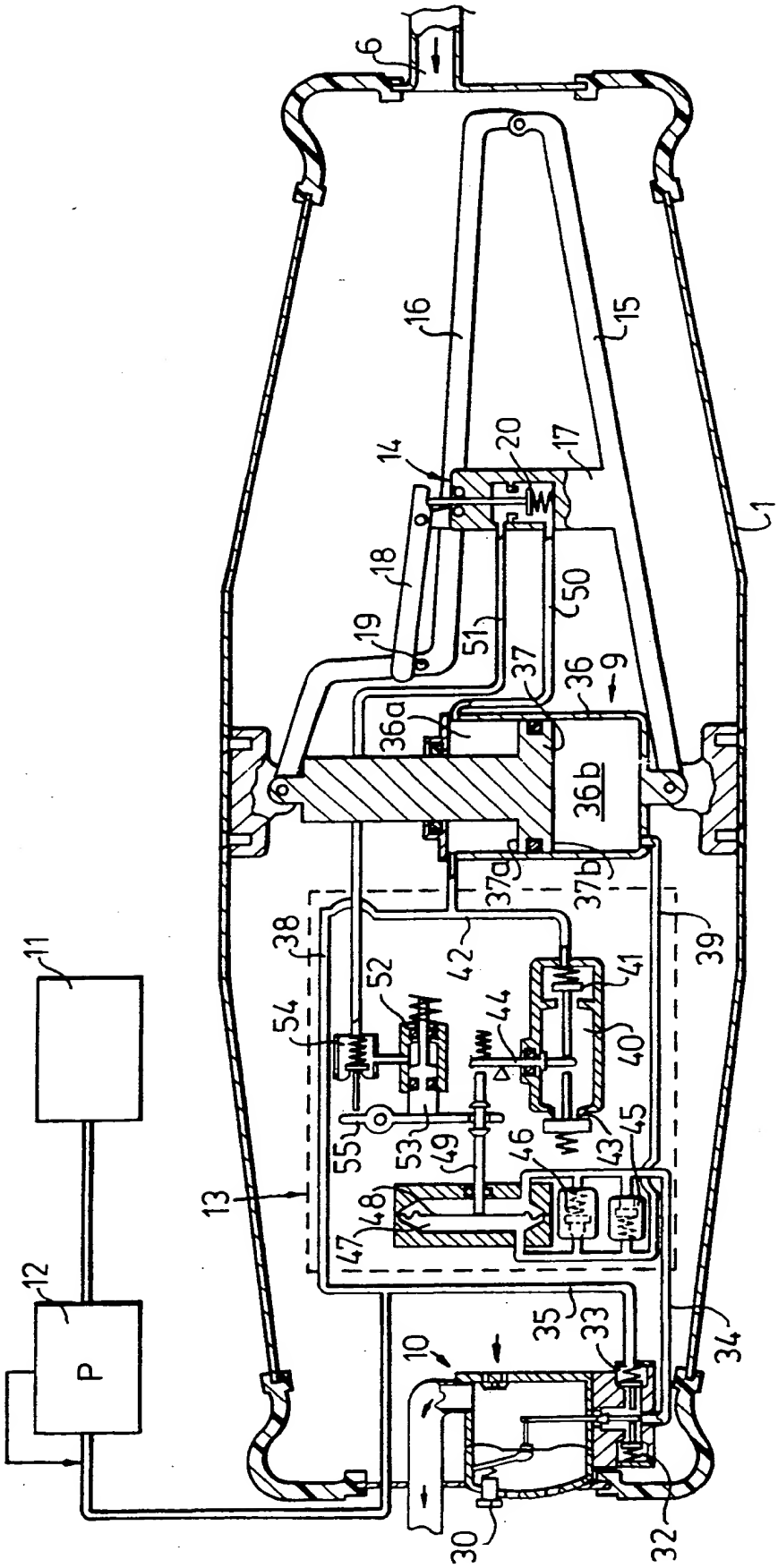


Fig. 3.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INTERNATIONAL SEARCH REPORT

International Application No PCT/NO 91/00052

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: A 62 B 7/04

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	A 62 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
Y	DE, C, 928810 (KURT ROSENBAUM) 10 June 1955, see page 2, line 19 - line 35; figures 2,3 --	1,8
Y	DE, C2, 3105637 (INTERSPIRO GMBH) 18 September 1986, see column 5, line 29 - line 64; figure 2 --	1,4
Y	GB, A, 2236254 (DRÄGERWERK AG) 3 April 1991, see abstract; figure 1 --	1,4
Y	EP, A1, 0087034 (CANOCEAN RESOURCES LTD) 31 August 1983, see abstract; figures 2,3 --	1,3

* Special categories of cited documents:[10]

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
2nd July 1991	1991 -07- 04
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	C. Westberg

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	US, A, 4793340 (OTTESTAD) 27 December 1988, see figures 1-6; claims 1-10 --	1-9

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. PCT/NO 91/00052

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the Swedish Patent Office EDP file on 91-05-29 The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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DE-C2- 3105637	86-09-18	NONE		
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